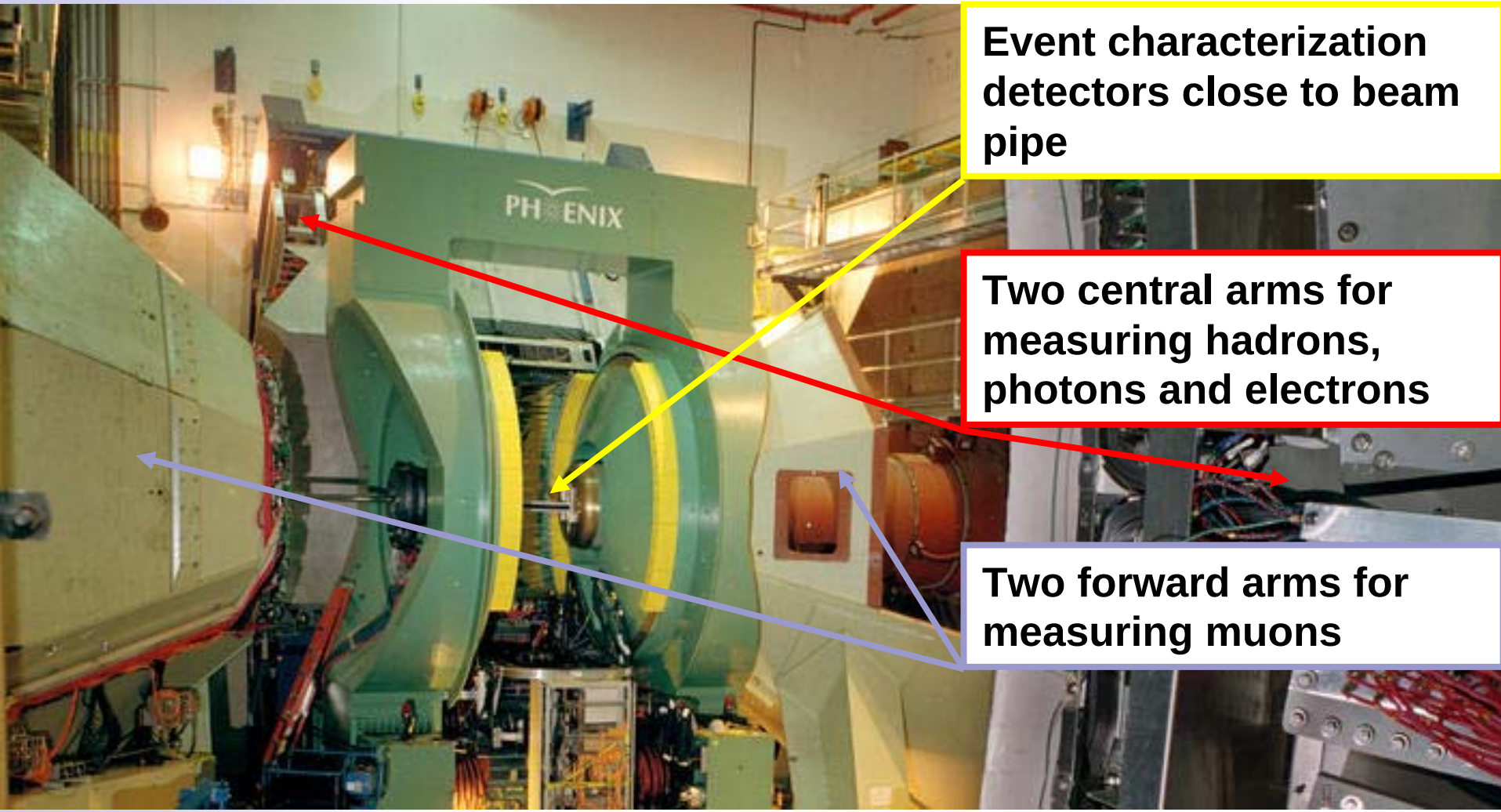
BNL, RHIC, PHENIX

Forward Calorimeters for the PHENIX Upgrade

PHENIX original



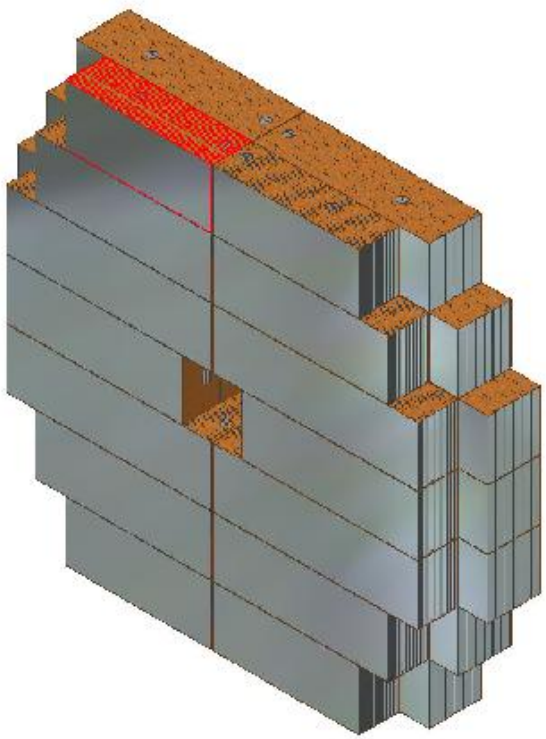
New physics -> old observables – new phase-space region

direct photons: p_T>2 GeV/c

direct leptons: isolation

jets: total energy, leading π^0;

π^0's



Detector specifications

π^0

Reasonable energy resolution for em probes;

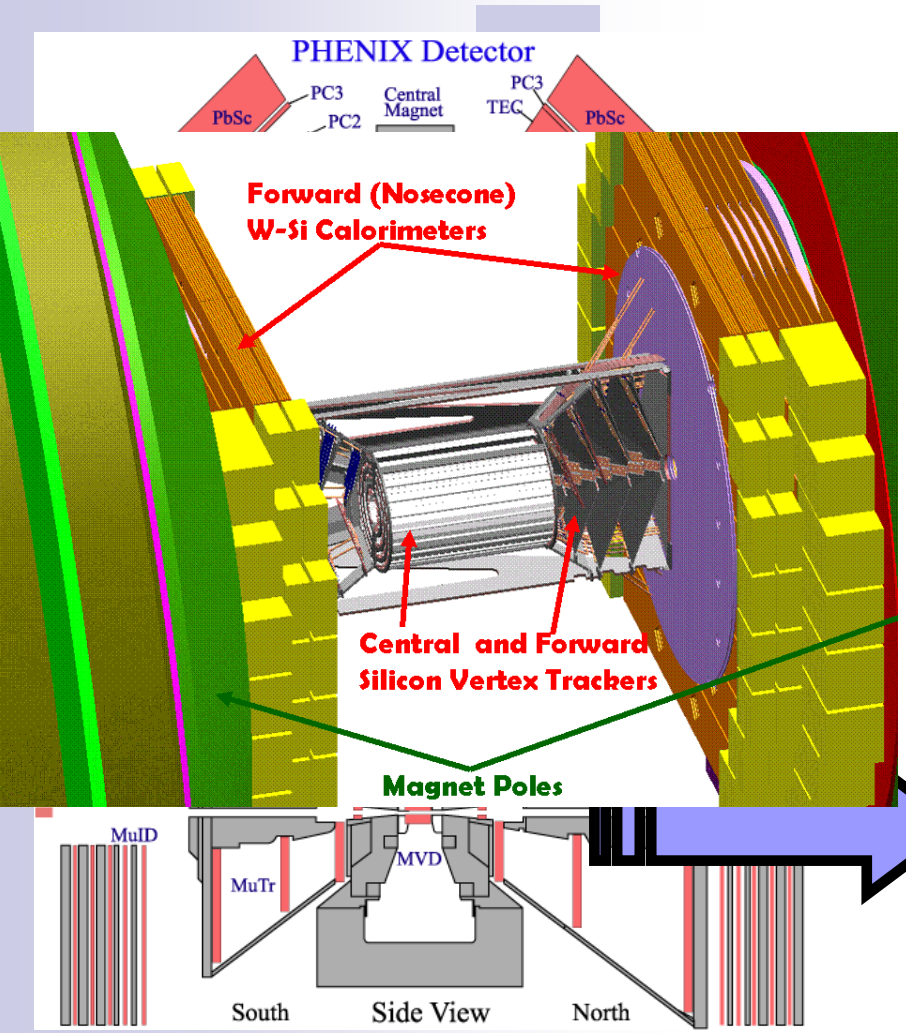
Separation between em and hadronic signals;

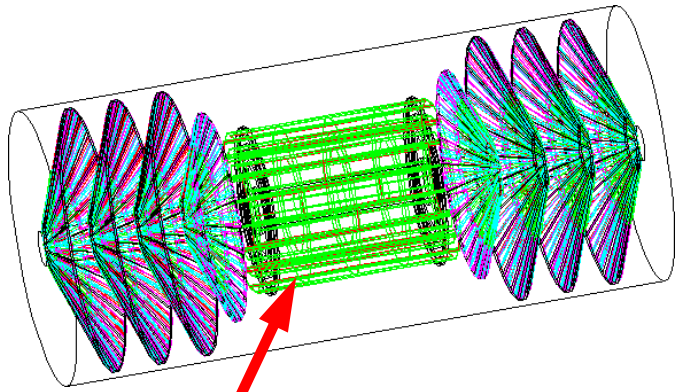
Ability to reconstruct overlapping photons;

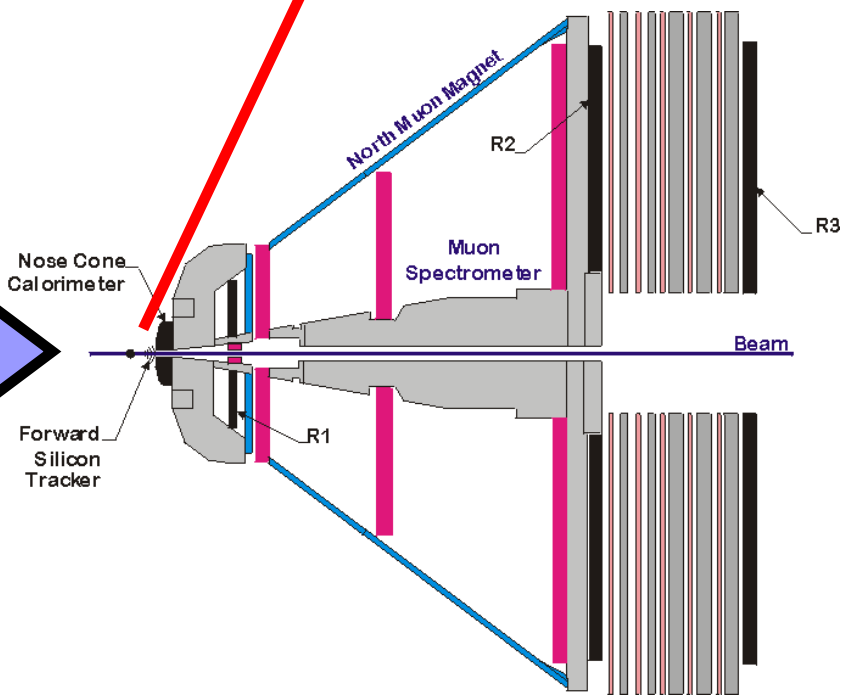
Jets

Cone energy measurements

PHENIX Upgrade

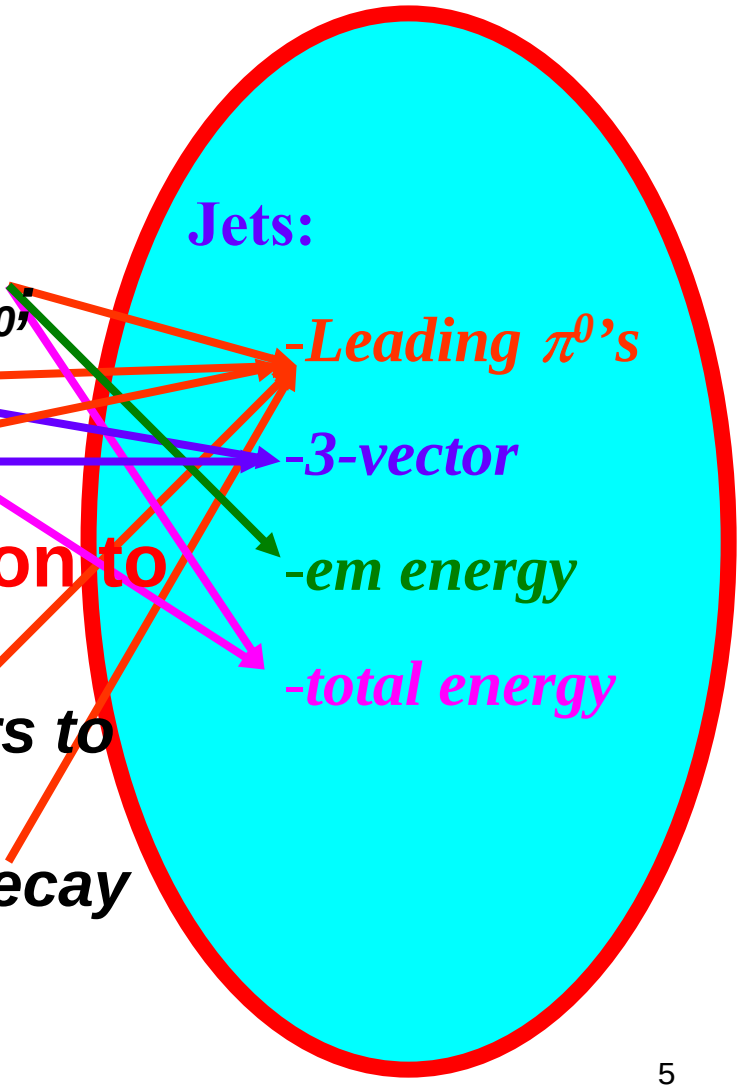






Considerations & compromises

- **Designed to produce clean sample of electromagnetic showers**
  - *Segmented em-section: 7 + 5 X_0*
  - *Hadronic segment: ~ 1 Λ_{abs}*
  - *Lateral segmentation: <$L_{moliere}$*
- **Optimized for π^0 reconstruction to 30 GeV/c**
  - *Converter and PreShower layers to see photons;*
  - *ShowerMax layer to measure decay asymmetry*

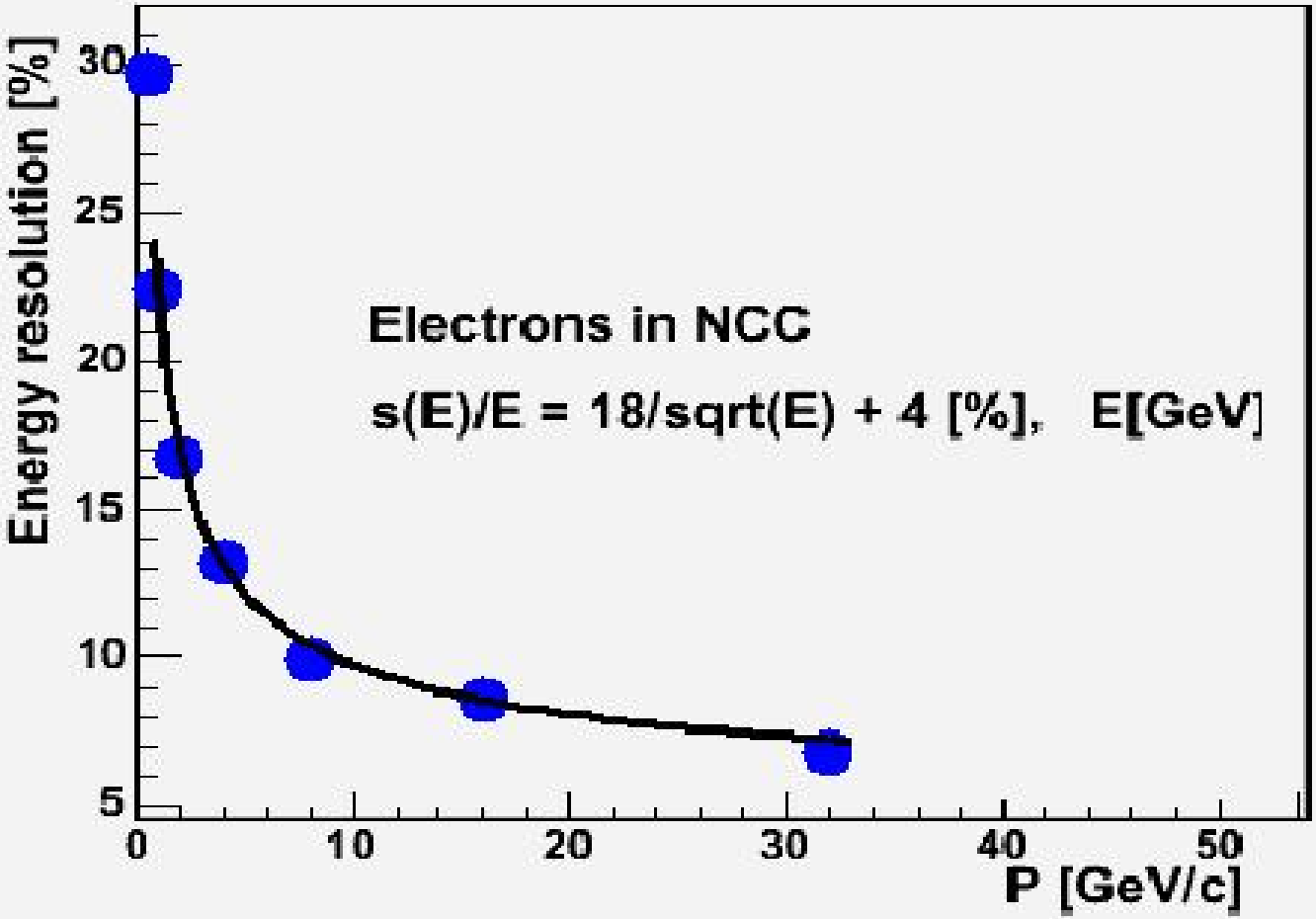


2-d pixilated strip sensors

Pad-structured sensors

15 x 15 mm²

Detector concept



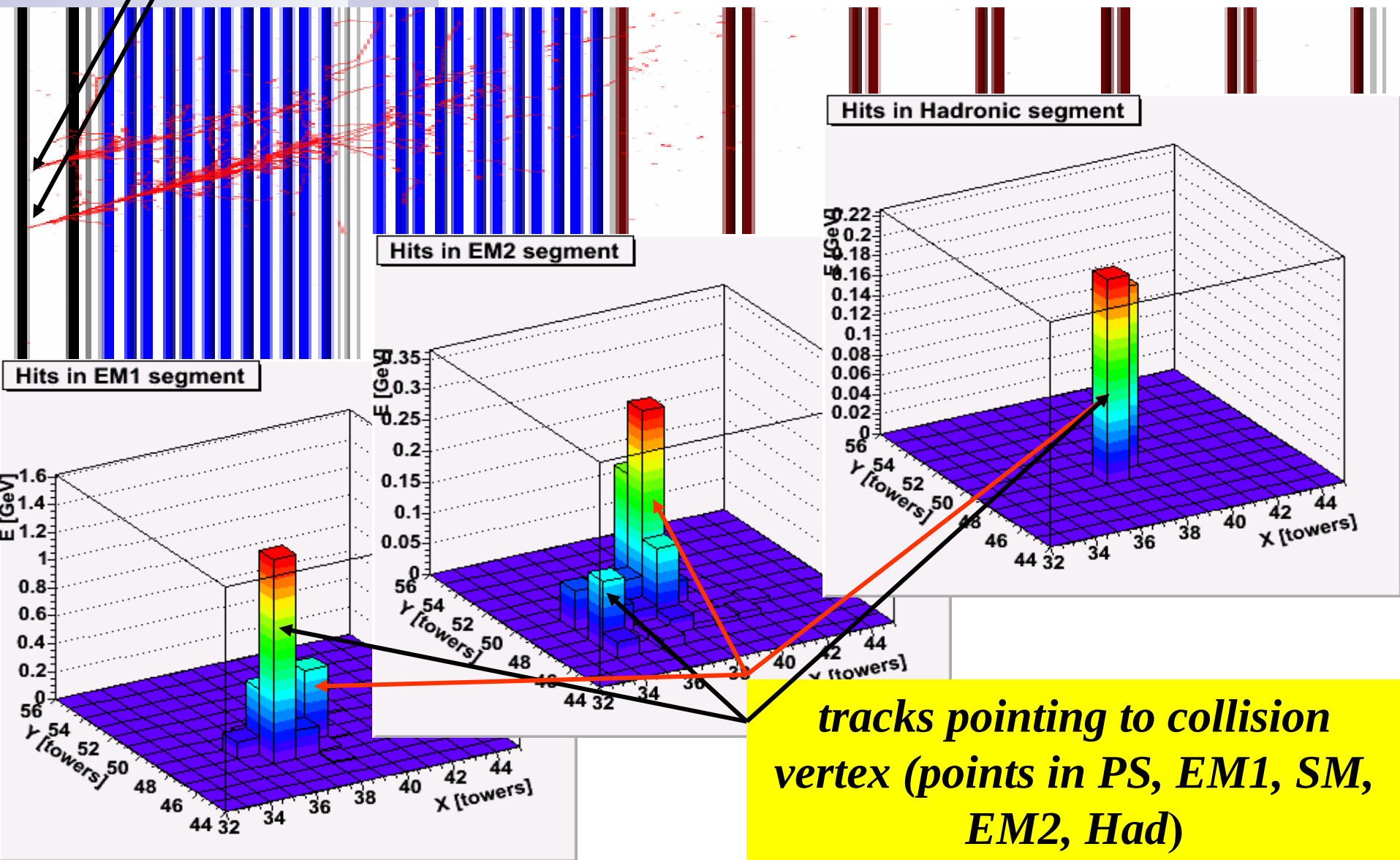
eV/c

eV/c

π^0 tracking: 5 GeV/c example

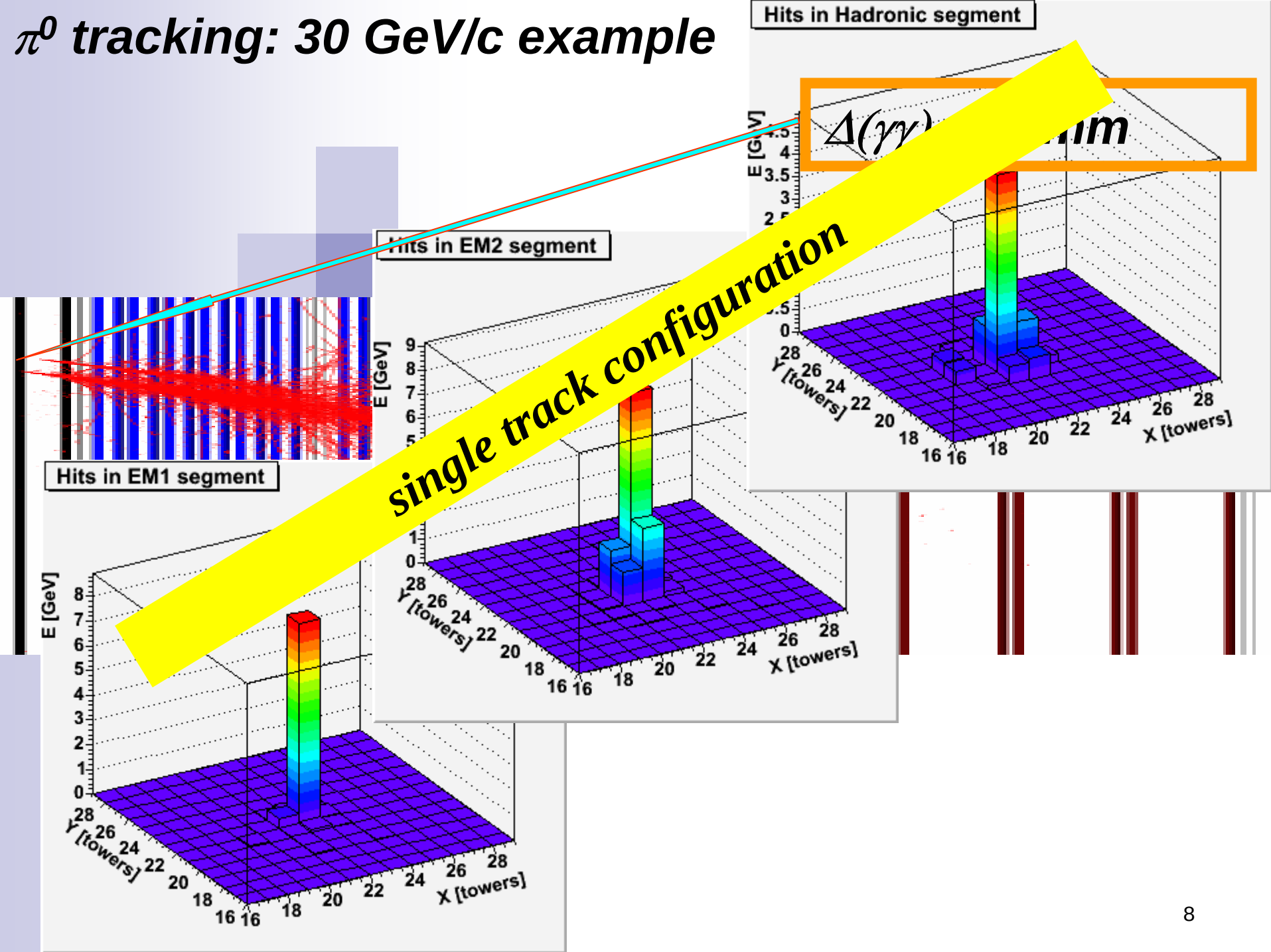
$\pi^0 \rightarrow \gamma\gamma$, d = 25 mm

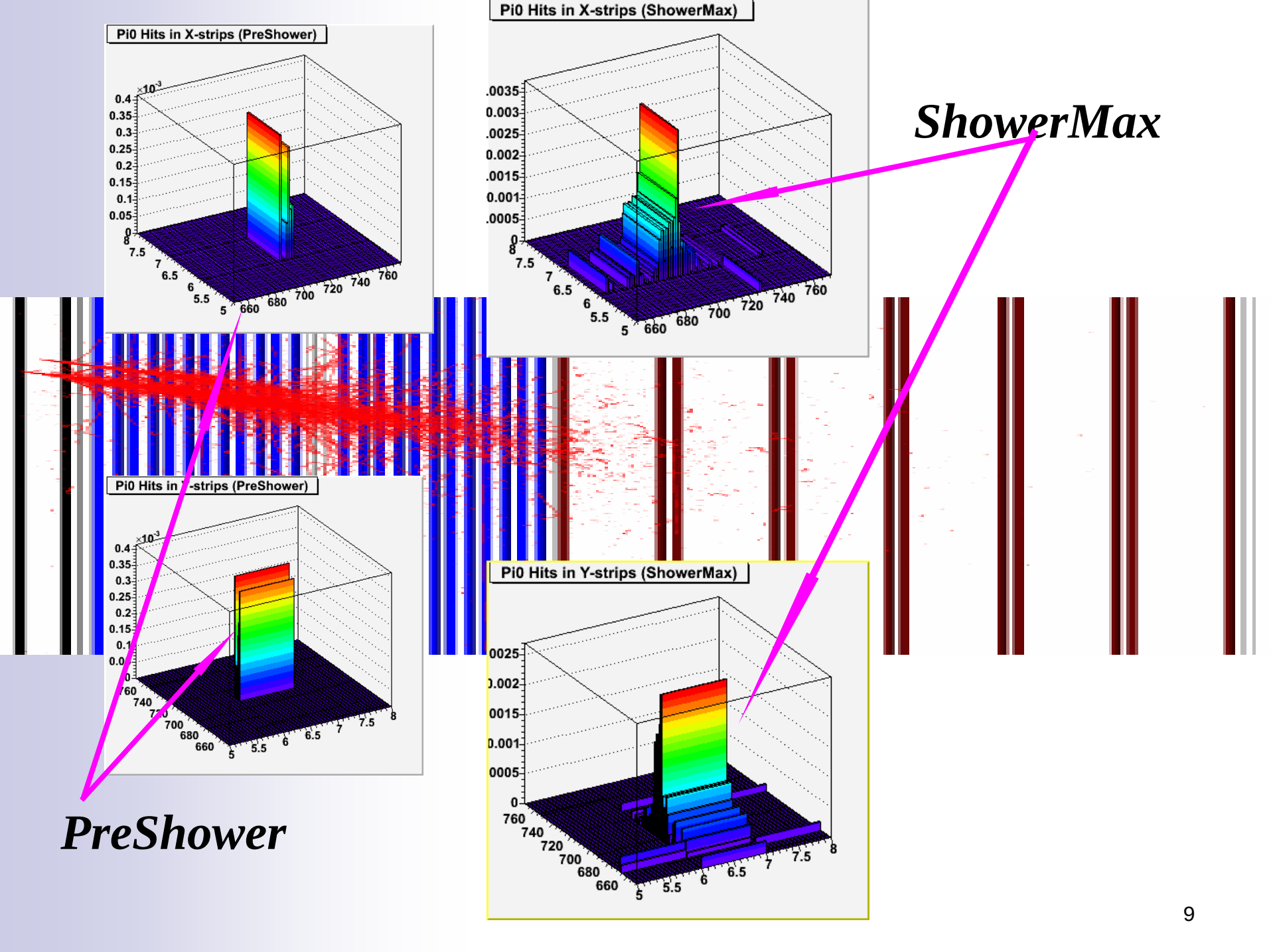
Multitrack configuration



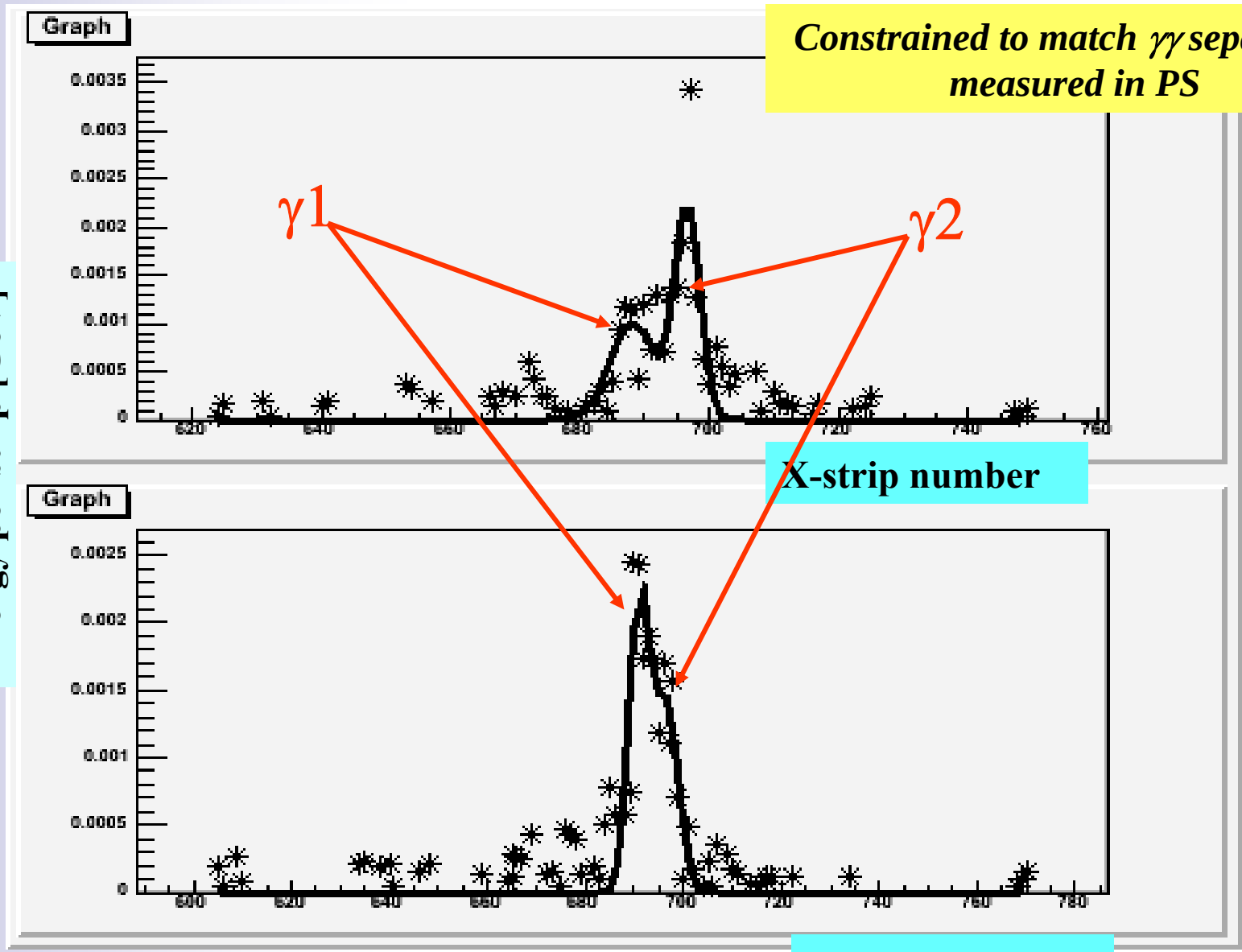
tracks pointing to collision vertex (points in PS, EM1, SM, EM2, Had)

π^0 tracking: 30 GeV/c example




Pi0 Hits in X-strips (PreShower)
Pi0 Hits in X-strips (ShowerMax)
ShowerMax
Pi0 Hits in Y-strips (PreShower)
Pi0 Hits in Y-strips (ShowerMax)
PreShower

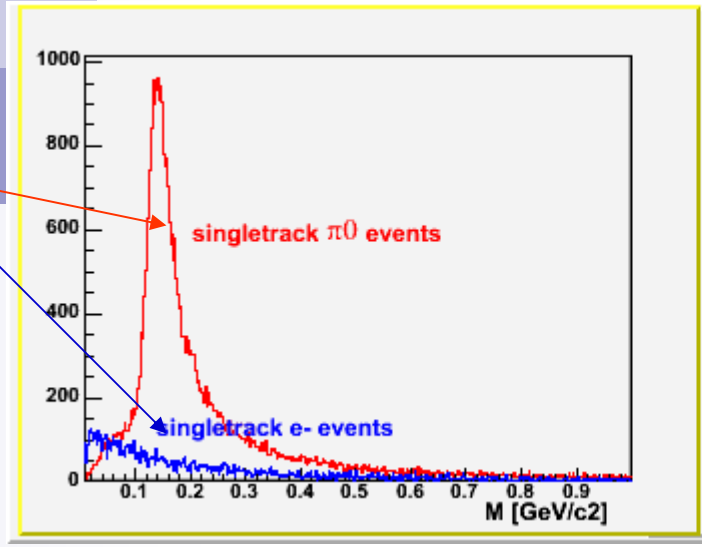
Fit to extract decay asymmetry

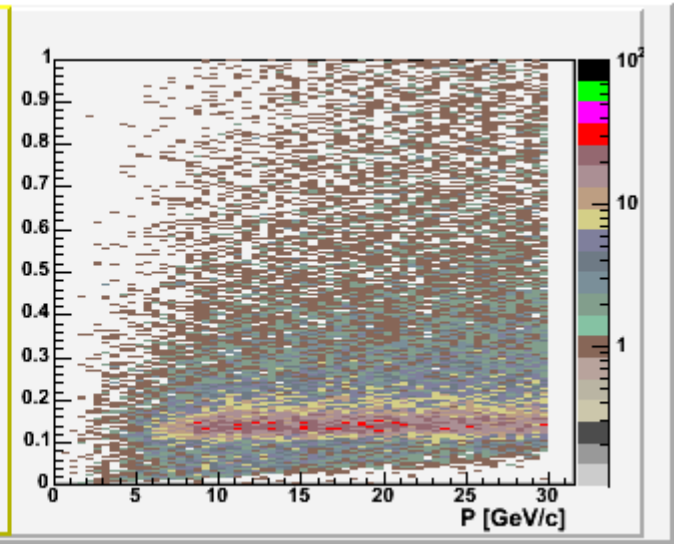


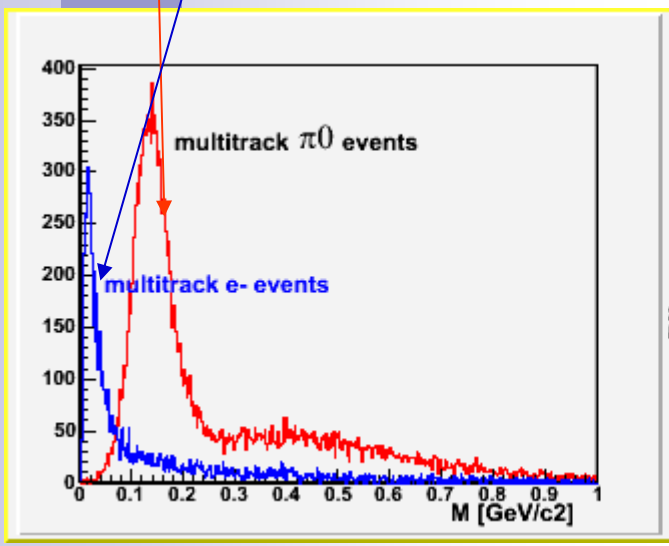
Constrained to match $\gamma\gamma$ separation measured in PS

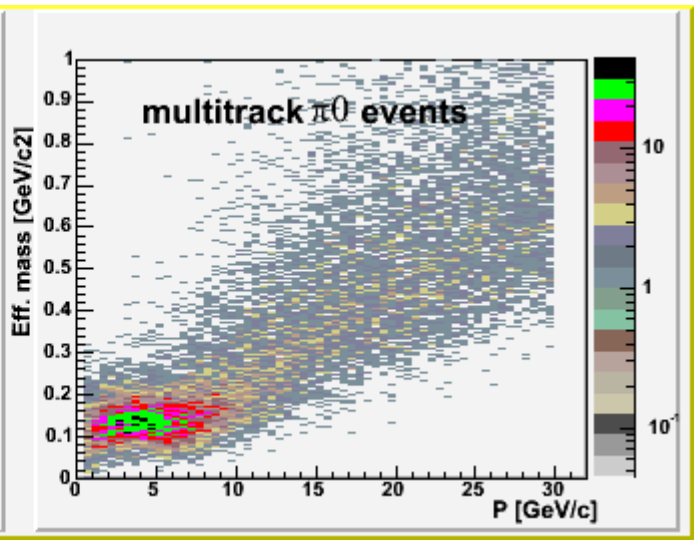
Concept works on simulated data, needs further tuning with simulated and test beam data

Single-particle (π^0 and e) simulation in NCC

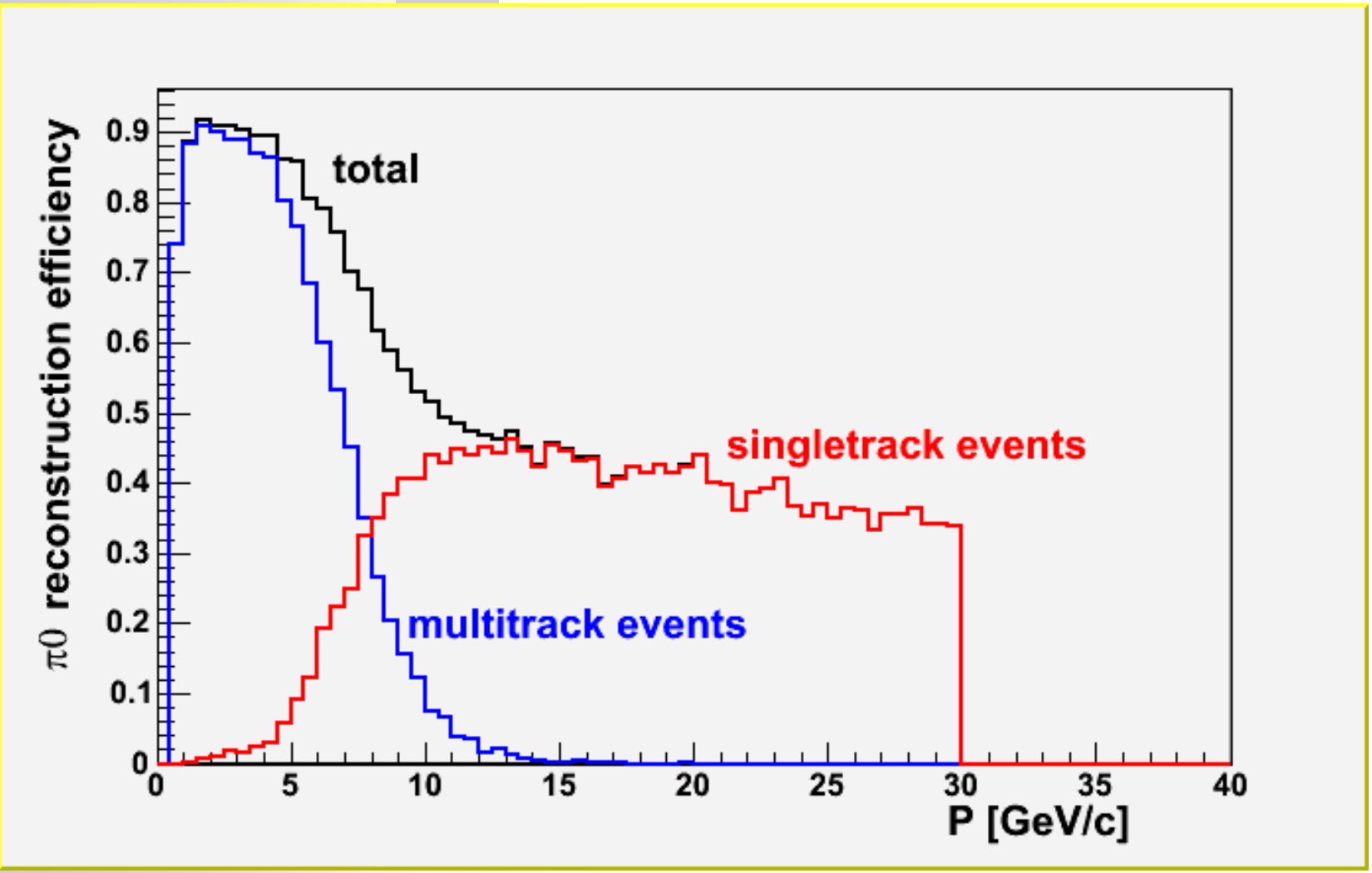








$\pi 0$ efficiency: zero approximation



Up-to-date

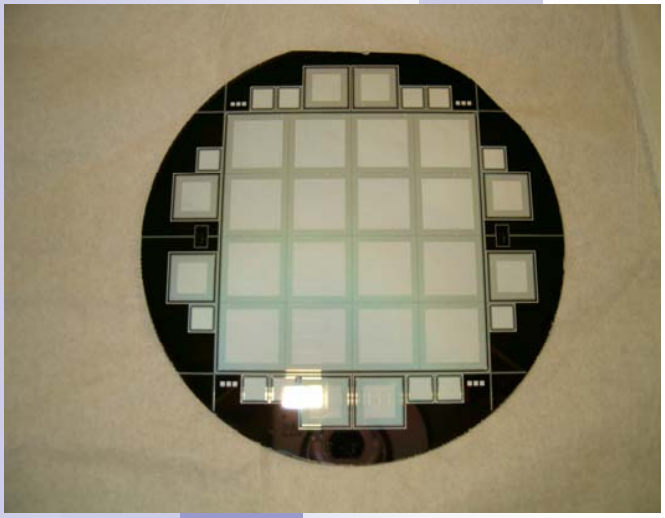
- Optimize detector, develop construction design;
- Develop, prototype and test Si sensors;
- Develop, prototype and test Si ladders (StriPixels and Pads);
- Develop, prototype and test readout.

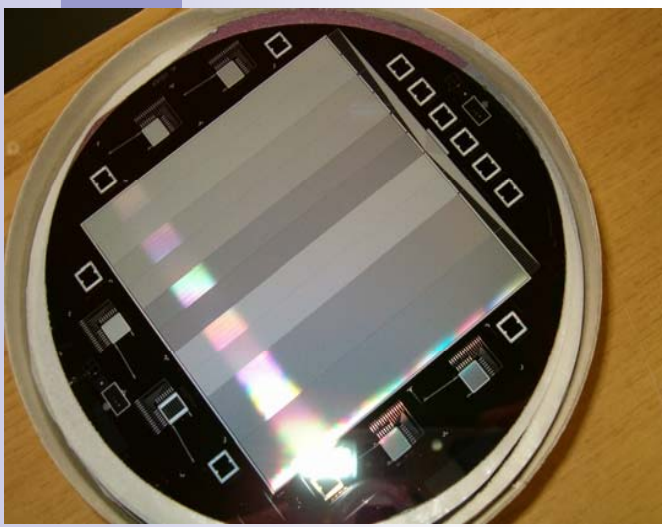
Major milestones:

Proof-of-principle prototype: built and tested in the beam in 2005;

System prototype to be constructed and tested in the beam in 2007.

Sensors



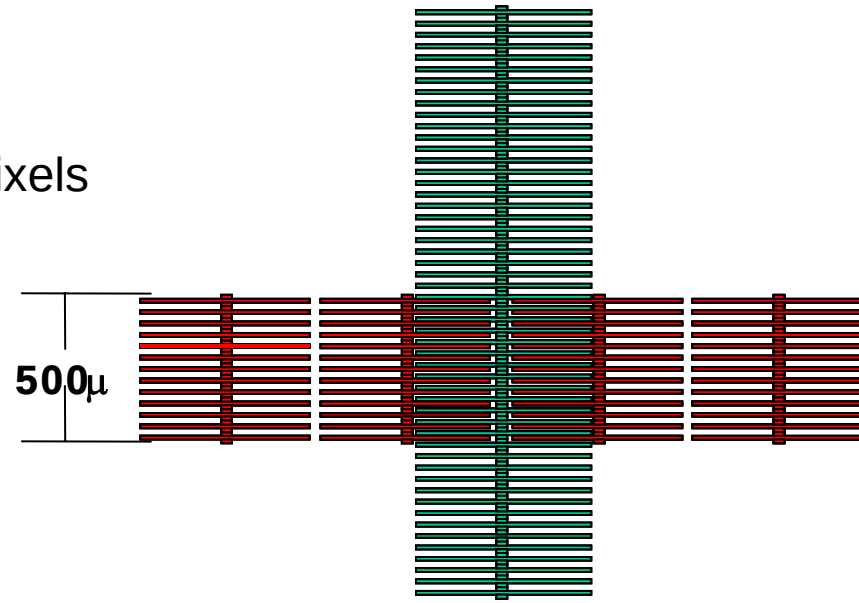


DC coupled, pad structured - ***completed***

AC coupled, pad structued - ***completed***

DC coupled, r-biased, pad structured – ***at ELMA and ON Semi***

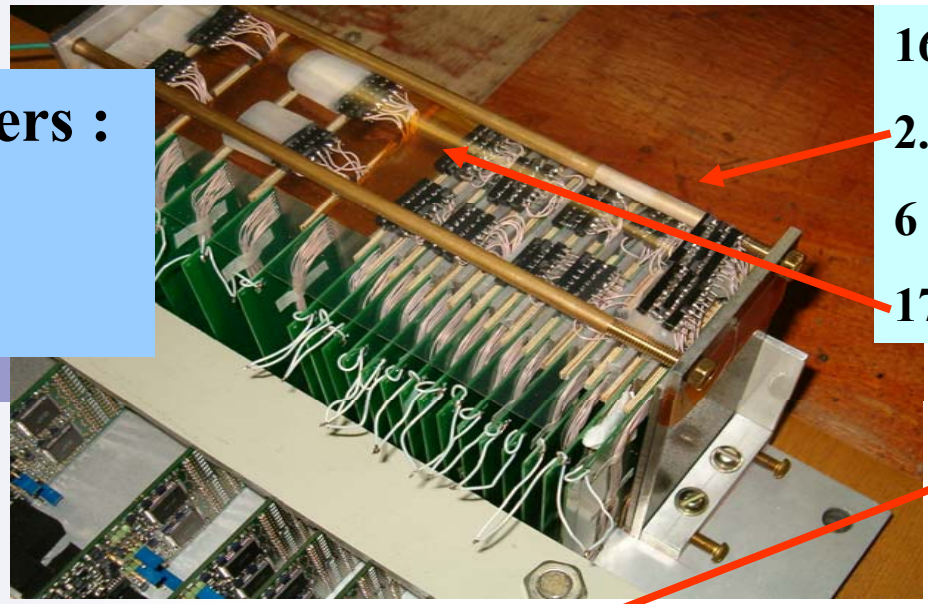
StriPixels



First confirmation that technology is robust

22 sampling layers :

4 EM + 2 HAD segments

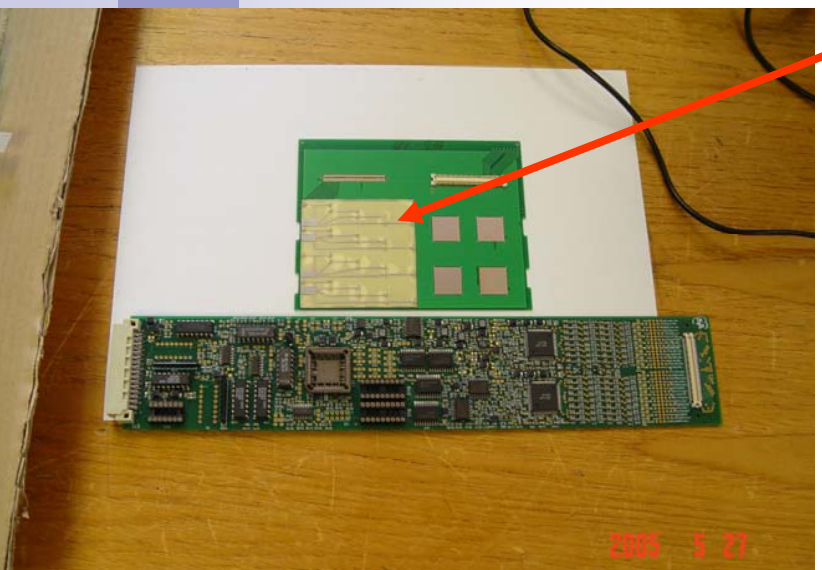


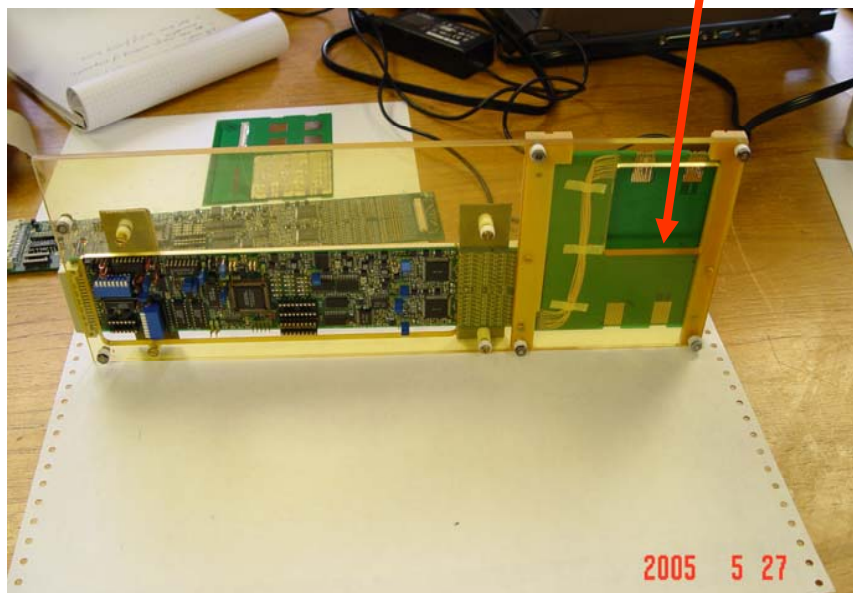
16 EM sampling cells:

2.5mm W + 2.5 mm ROU

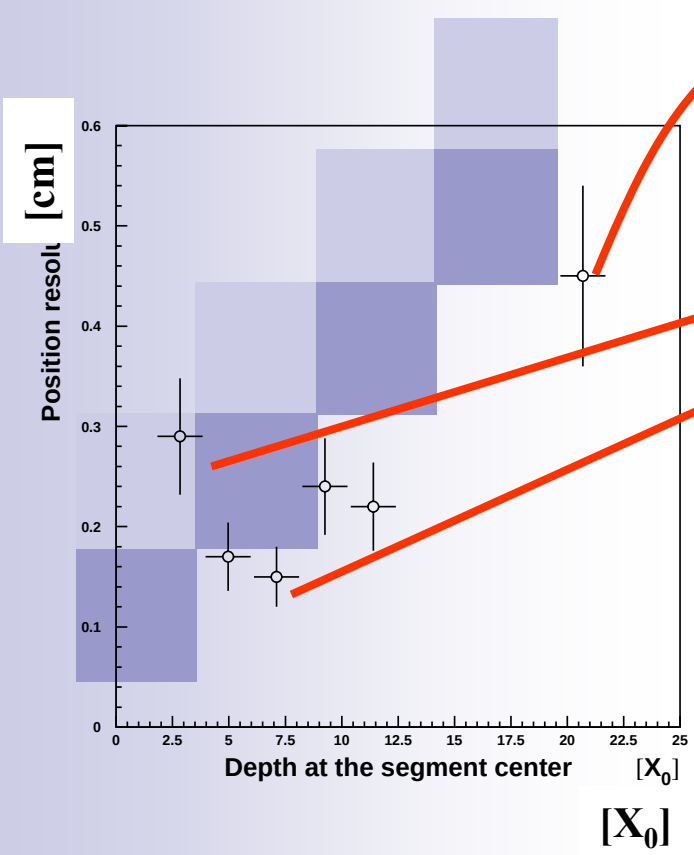
6 HAD sampling cells:

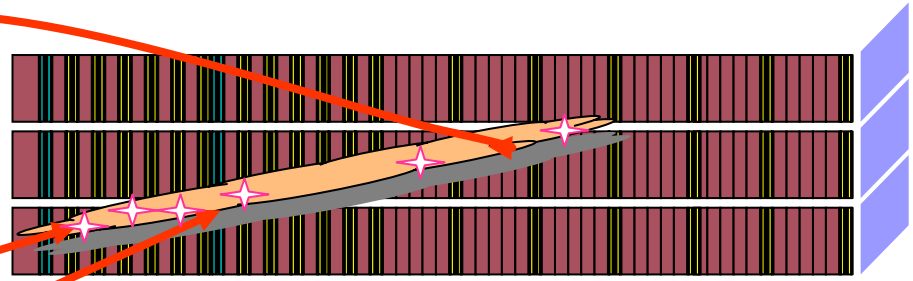
17 mm W + 2.5 mm ROU



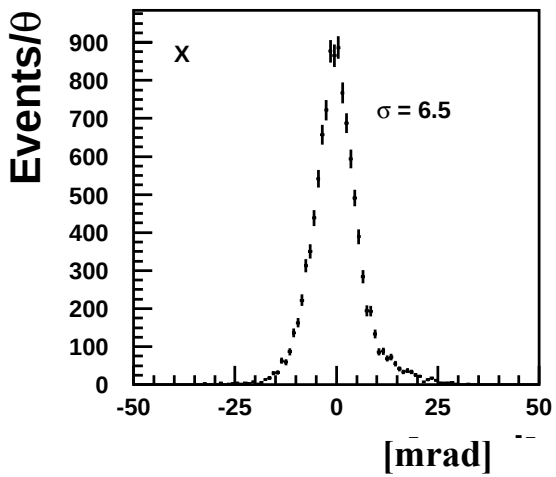


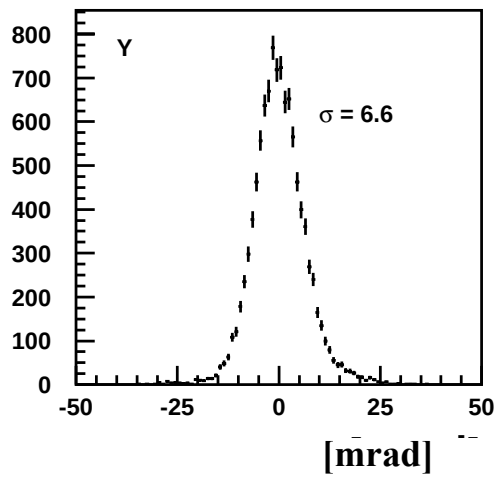
Position and directional measurements





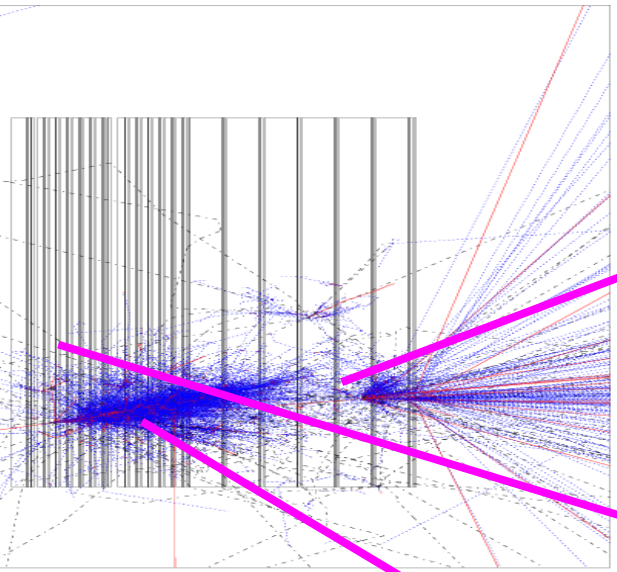
Vector pointing towards vertex

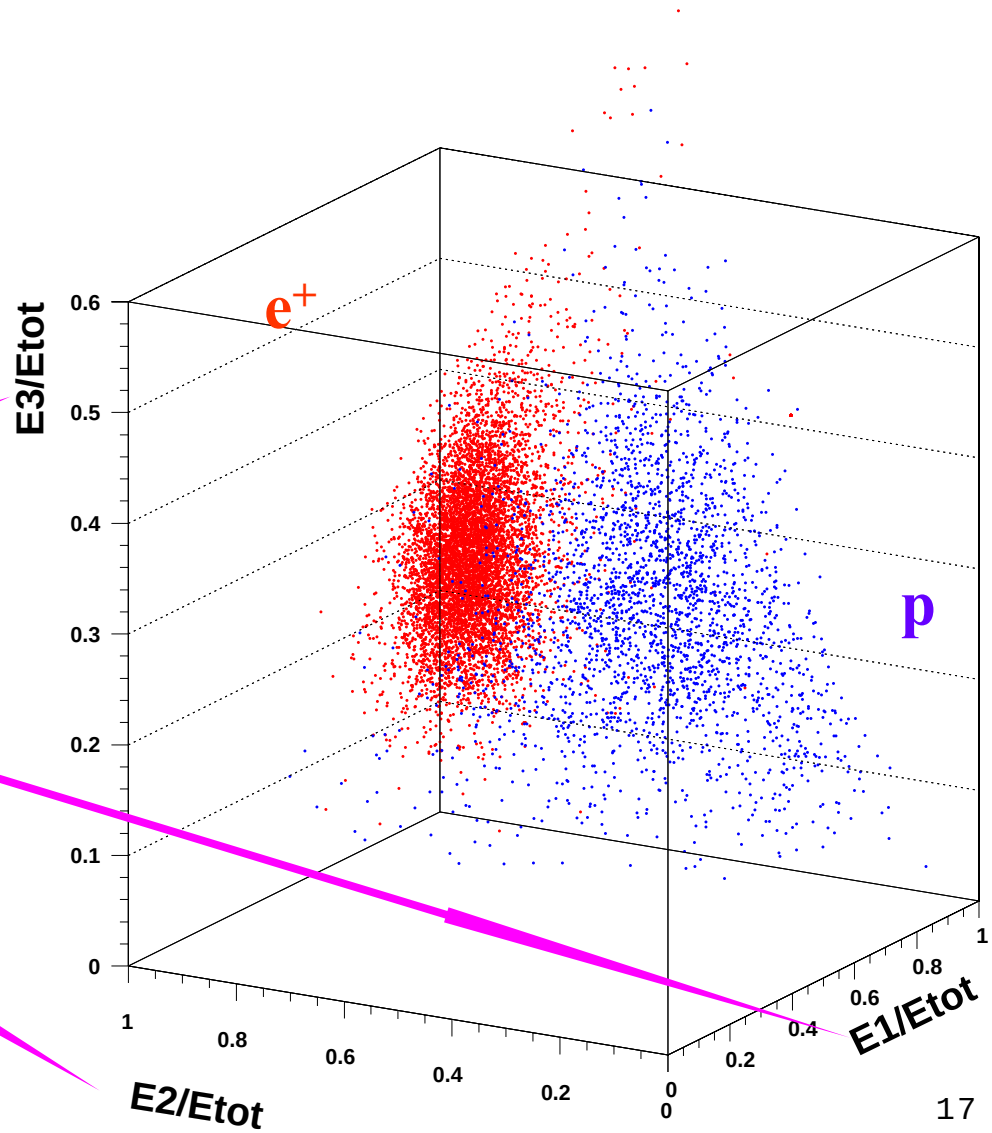




e/h separation: works but … more data needed.

Next test-beam experiment in 2007



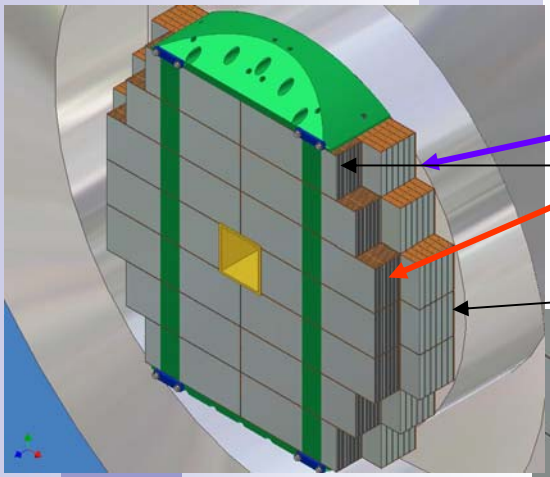


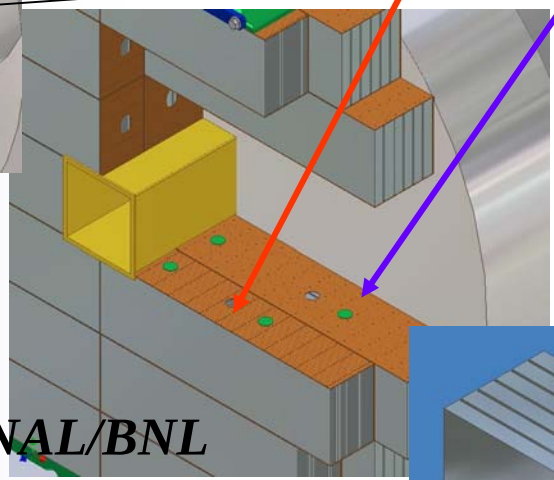
Calorimeter design

Assembly unit: *Brick*

Electomagnetic (14)

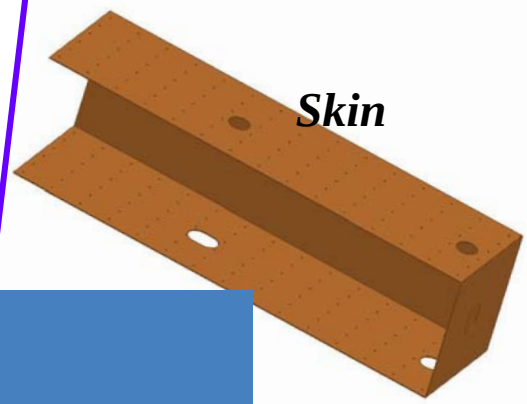
Hadronic (14)

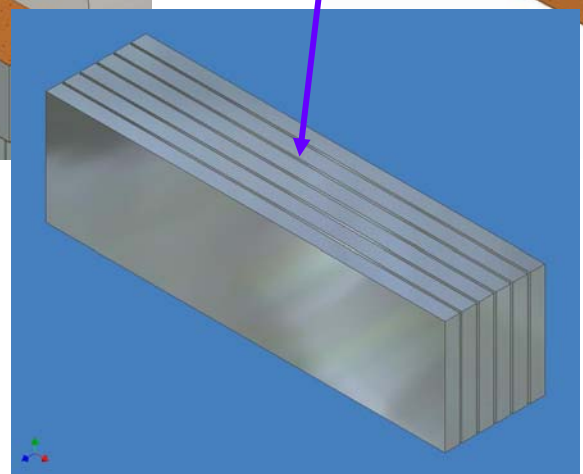




2 x 5 sensors minimum

2 x 7 sensors maximum





Design: JINR(Dubna)/FNAL/BNL

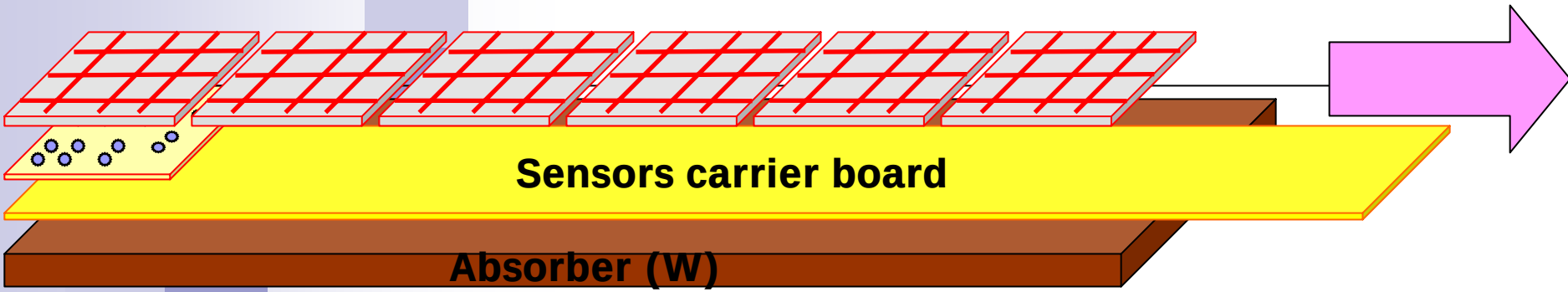
W plates: US

Mechanics: JINR(Dubna)

Assembly: BNL

ROU's not shown

Pad-structured ROU (ladder) design



Detector ladder attached to the W plate

Decoupling capacitors and bias resistors are part of hybrid amplifiers

Interconnect board to allow replacement of the sensor (last resort ...). Have bonding pads to wire-bond sensors and soldering pads (or wires) to solder to the carrier board.

Layout: BNL/MSU

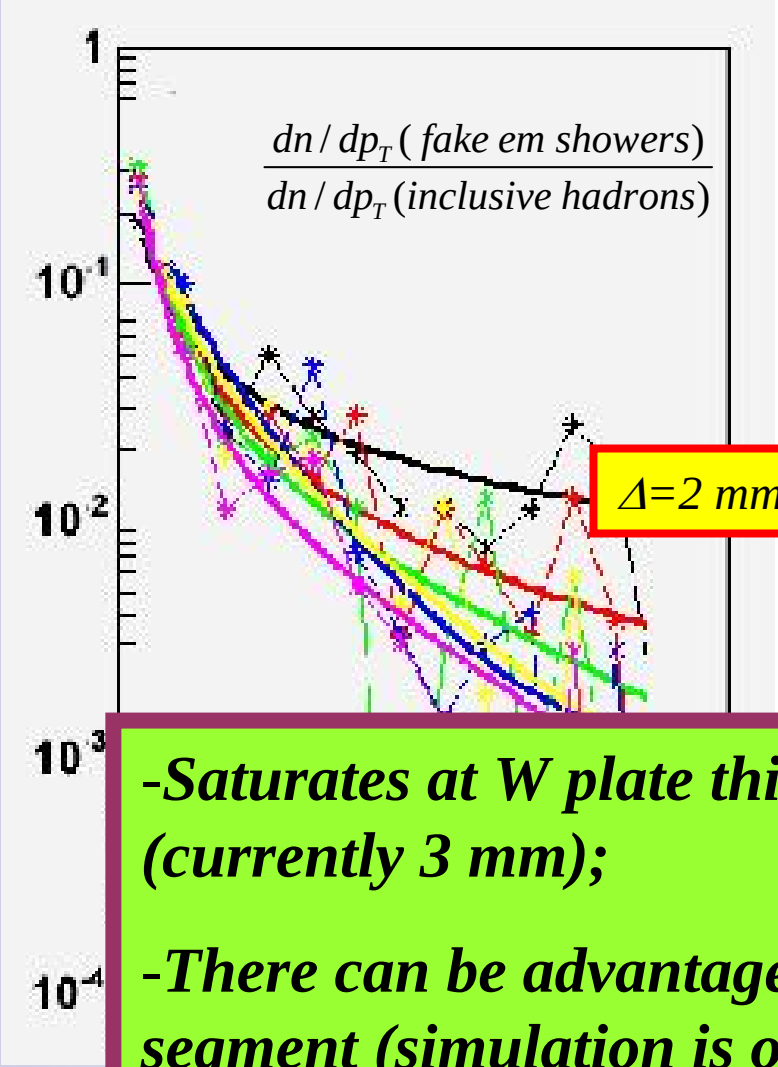
Implementation: BNL/Komposit (Ekaterinbourg, Russia)

Summary

- ***There is the most ambitious calorimeter project I ever considered ……***
- ***It will work as effective π^0 reconstruction tool if tower occupancy is below 10% and vertex-to-detector separation is sufficient for two photons from $\pi 0$ decay to spread for more then ~.2$R_{moliere}$***
- ***By the end of 2007 we will***
  - ***optimize design and performance;***
  - ***test production chain;***
  - ***accumulate test beam data and build analysis chain;***
- ***If expectations are confirmed we will follow this design (with constrains removed) for e-RHIC detector at BNL.***

BACKUP's

Optimization: plate thicknesses vs energy resolution and hadron rejection



© *6 sampling cells per segment (cost)*

2 – 5 mm plates in EM1/EM2

11-16 % sampling term to em-resolution at 1 GeV

thicker plates in em segments improve

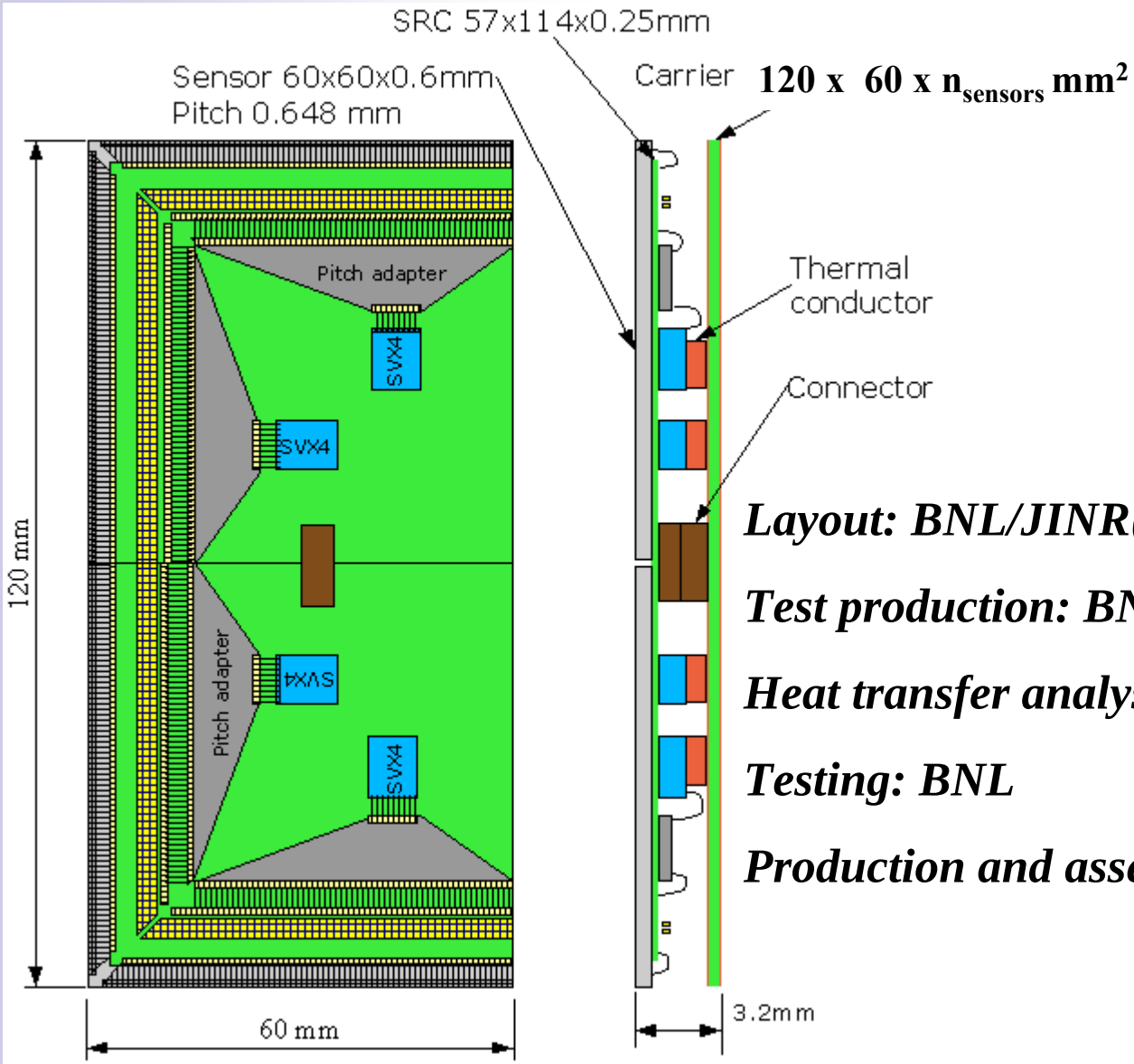
-em resolution at high energies;

-Saturates at W plate thickness in EM segments > 3mm (currently 3 mm);

-There can be advantage in switching to Pb in hadronic segment (simulation is ongoing).

-Jet energy measurements

StriPixel ROU (ladder) design



Layout: BNL/JINR(Dubna)

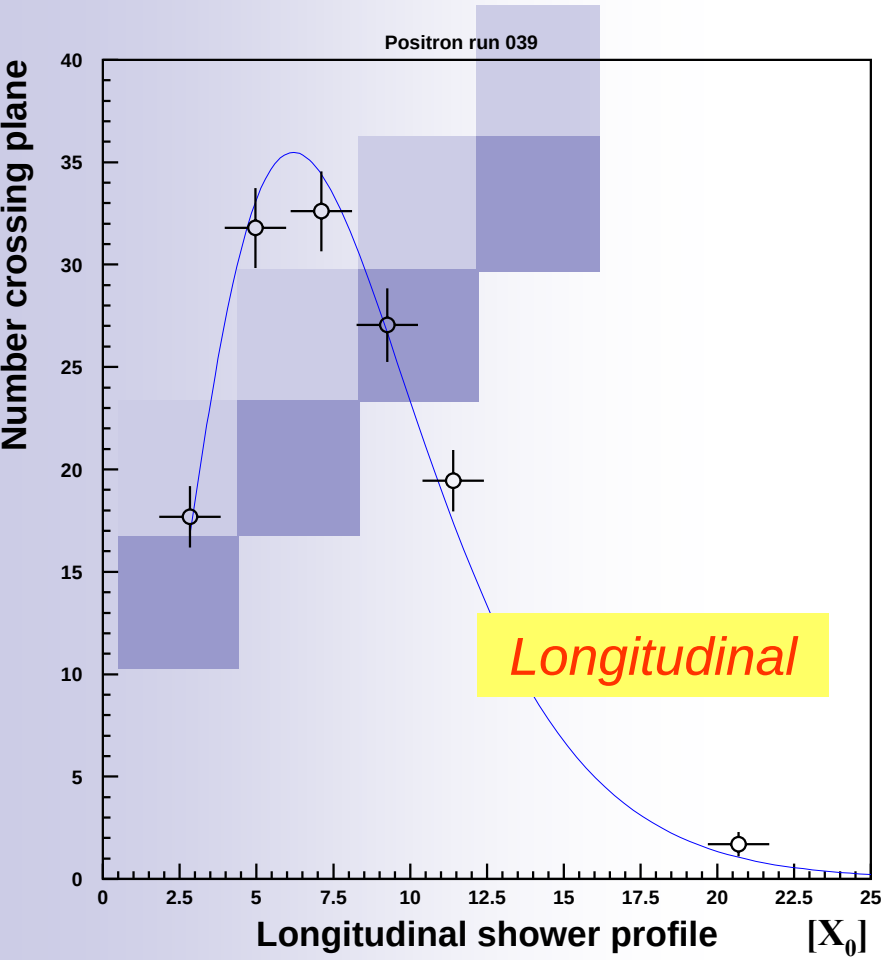
Test production: BNL/FNAL

Heat transfer analysis: FNAL

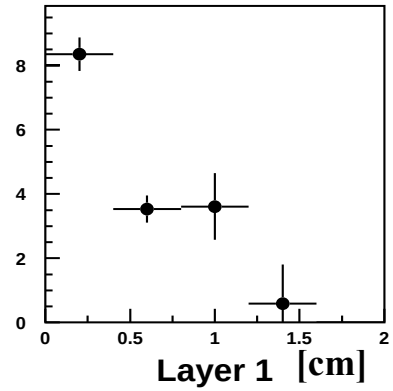
Testing: BNL

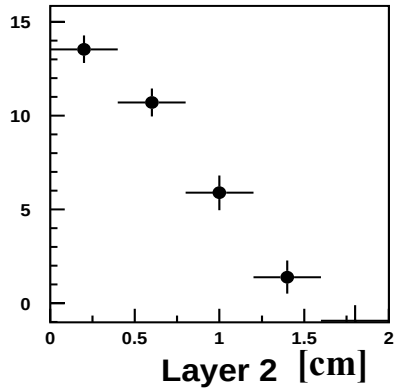
Production and assembly: BNL/JINR(Dubna)

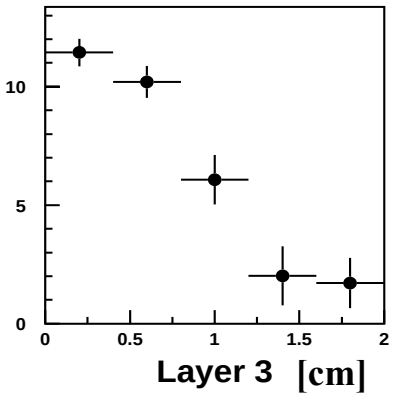
Shower development

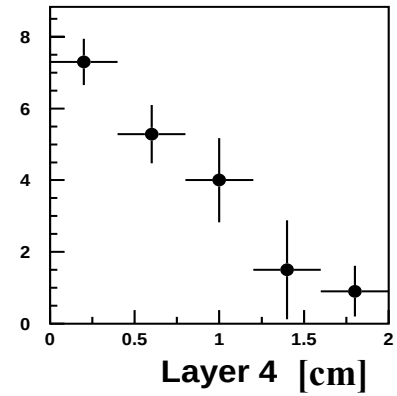


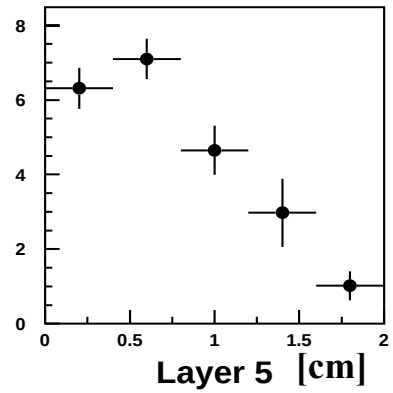
Lateral

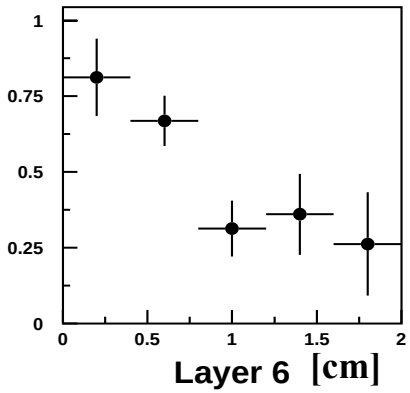












Energy measurements

Measured resolution ~ 11% driven by very thick plates in Hadronic segments